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Biology of *Xylocopa (Xylocopa) violacea* (L., 1758) (Hymenoptera: apidae): nest morphology.

Abstract – Fifty-nine nests of *Xylocopa violacea* in dried canes and 11 in poles were analysed. Two branched nests in a dry and rotten trunk were also examined. Poles and canes were artificial substrata, as they were used as supports for fruit and vegetable farming. The poles were derived from *Castanea sativa* and, to a lesser extent, from *Ficus carica*, the canes from *Arundo donax*. Eight parameters related to the morphology and position of the canes, and 13 related to nests completed and abandoned in poles were considered. Furthermore, the digging behavior was followed up in 10 nests. In poles and branches, nest entrance was mainly in the N-S direction; the most frequent diameter was 11 mm: 52/61 (85.2%) entrances found were situated at a height exceeding 41% of the total length of the poles or branches. The canes used by females for nesting were at a minimum distance of 860 mm from the ground; the entrance was 9-14.5 mm in diameter. Nests in canes generally occupied the first internode. Damaged canes and poles or those at ground level were systematically avoided for nesting. These peculiarities can be considered as antipredatory measures against *Cremastogaster scutellaris*, *Podarcis sicula* and other females of *X. violacea*.

Riassunto – 59 nidi sono stati esaminati in canne secche e tagliate ed 11 in pali. Due nidi non ramificati in un tronco secco sono stati successivamente analizzati. Pali e canne sono usati come supporti per i vegetali coltivati, cosicchè essi sono artificiali. I pali derivano da *Castanea sativa* e molto meno da *Ficus carica*; le canne derivano da *Arundo donax*. Otto misure riguardanti morfologia e posizione della canna sono state prese; 13 misure concernenti nidi ultimati ed abbandonati in pali. E' stato seguito il comportamento di scavo in 10 nidi in pali. In pali e rami la direzione dell'ingresso è soprattutto nord-sud. Il diametro più frequente è 11 mm ed è scavato solitamente al di sopra del 41% della lunghezza totale del palo o ramo. Le canne usate per nidificare sono poste ad un'altezza minima di 860 mm dal suolo; l'ingresso ha un diametro di 9-14.5 mm. Nelle canne l'internodo più frequentemente usato è il primo. Canne e pali posti al suolo o troppo danneggiate sono sistematicamente evitate per l'istallazione di un nido. Tutte le peculiarità metriche sono considerabili come misure antipredatorie contro *Cremastogaster scutellaris*, *Podarcis sicula* e altre femmine di *X. violacea*.

Key Words – *Xylocopa violacea*, Apidae, nest morphology, nest biometrics, southern Italy.

Introduction

The species of the genus *Xylocopa* Latreille 1802, are known as carpenter bees since they all have the same nest-digging behavior (Iwata, 1972;

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Hurd & Moure, 1963): they generally dig tunnels in several directions inside the trunk, so that the nest appears branched. Some species can also nest in the internodes of canes or bomboo e.g.: Hurd & Moure, 1960). Nest morphology and substratum type are no doubt the characters that have been studied more extensively and exhaustively in reproductive biology (e.g.: Hurd, 1955, 1956-a, b, 1958-a, b, 1960; Hurd & Moure, 1963; Janzen, 1964, 1966; O'Brien & Hurd, 1965; O'Brien & O'Brien, 1966; Sage, 1968; Bonelli, 1974, 1976; Jacson & Woodbury, 1976; Smith & Whitford, 1978; Ben Mordechai et al., 1978; Barrows, 1980; Camillo & Garofalo, 1982; Gerling, 1982; Gerling et al., 1983; Fowler, 1983; Camillo et al., 1986).

Xylocopa (Xylocopa) violacea (L., 1758) inhabits the mid-western Palaearctic region (Maa, 1938, 1955; Hurd & Moure, 1963; Tkalcu, 1968; Warncke, 1976; Hurd, 1978). In Italy it is widespread all over the peninsula from sea level to above 1100 m (Pescasseroli: Abruzzo, central Italy; Tkalcu, 1968). It is also present in Sardinia and Sicily, as well as on some minor islands as Capraia and Giglio (Mantero, 1905; Masi, 1931; Soika, 1932; Alfken, 1937; Guiglia, 1941; Comba, 1964; Bonelli, 1966, 1967; Comba & Comba, 1991).

The knowledge of *X. violacea* biology is only fragmentary (e.g.: Friese, 1923; Parker, 1924; Hardouin, 1943; Grasseè, 1951; Grandi, 1951, 1955, 1961; Van Lith, 1955; Bonelli, 1966, 1967, 1974, 1976; Grzimek, 1970; Kugler, 1972; Janvier, 1977; Ricciardelli-D'Albore, 1979; Campadelli, 1983; Dindo et al., 1992; Vicidomini & Picariello, 1994). This paper describes the nest-digging behavior of *X. violacea* and the main characteristics of nest morphology.

Materials and methods

The following nests were examined: 59 in horizontally arranged dry canes deriving from *Arundo donax*, 8 in vertical poles deriving from *Castanea sativa*, 1 in dry branches of *Prunus cerasus*, 1 in a horizontal pole of *Castanea sativa*, 1 in a rotten tree of *Prunus persica*. Two branched nests in a dry trunk of *Prunus persica* were also analyzed. Poles and canes were artificial substrata, since they were used as supports for fruit and vegetable farming. From 1986 to 1992 and in 1994 all the nests present in the study area were removed and studied, but in 1993 sampling was incomplete. Eight parameters related to the morphology and position of the canes were considered: preservation state of the wood on a chromatic basis (B: yellow surface = very good preservation state. G: grey surface = good preservation state. S: grey surface variegated with black = mediocre preservation state. M: grey and black surface = rotten wood); location of nest entrance; length of cane internodes; thickness of the cane wall at the nest entrance; greatest diameter of the nest entrance; distance of the cane from the ground; number of the punched septa of the cane; nest location within the study area. Thirteen characters were taken into consideration analyzing 11 complete nests and 48 abandoned nests inside poles and branches: substratum type (Pp = poles. Rs = dry branch on the tree. Rr = cut-off dry branch); preservation state of the wood (M = all rotten. Me = exteriorly rotten. 1/2M = higher half of the substratum length rotten. 1/4M = higher quarter of the

substratum length rotten); use for farmers (Sc = plant support. Sr = net support. No = no function); height of the substratum; depth and location of the entrance; distance of the entrance from the top and the base of the substratum; length of the ascending and descending nest tunnels; diameter and circumference of the substratum at the entrance level; for horizontal poles and branches, the distance from the ground was also considered.

In addition, nest-digging behavior was followed up in 10 out of the 13 nests observed inside poles and branches.

For species identification I referred to: Rondani (1874), Friese (1923), Berlese (1925), Grasseè (1951), Grandi (1951; 1961), Grzimek (1970), Chinery (1985), Chvala & Zahradnik (1991), Pagliano & Nobile (1993).

Results

Abandoned Nests.

The substrata where excavation has been started but not finished are referred to as abandoned nests: they were observed only in solid wooden substrata, i.e. poles and branches. Females recognize and explore the substratum, exhibiting a series of peculiar behaviors, which will be described in a future paper (Vicidomini, in preparation). When females recognize a suitable wooden substratum, they cut its surface with their jaws, as if they made a preliminary test, starting excavation of a circular hole. The hole is very often abandoned for the hardness of the wooden central portion. It can also be left for other minor causes, such as anthropic activity, presence of ants, presence of a xylofagous insect tunnel in the same place where excavation has been started. Poles and branches with numerous woodworms (very often obtained from *F. carica*), those containing ant nests or too much cracked and rotten are never inspected or are abandoned. Poles and branches that are too narrow, too short, or lying on the ground are also neglected. Nests may be abandoned at a more advanced level of excavation: in fact, 7 abandoned tunnels from 15 to 103 mm long were examined (Tab. I).

Holes excavated in the current season are light yellow, while those excavated in a previous season are dark brown. Nest digging is started in the poles and branches that meet requirements before and during digging.

The small poles used in agriculture in these areas are essentially derived from *C. sativa* and, to a smaller extent, from *Ficus carica*. All poles with complete or abandoned nests are derived from *C. sativa*.

Nest digging – Poles and Branches.

Each nest is founded by a single female.

Females start excavating a circular hole in the less compact area of the pole or branch. The hole is orthogonal to the substratum surface, and has a depth of 17-42 mm (mean = 26.11; St. Dev. = 9.14); in one case a depth of 100 mm was observed (mean, including this case = 33.5; St. Dev. = 24.90). The hole can be central or, as very often happens, eccentric, depending on wood hardness.

The hole diameter was 10-12 mm in 85.2% of the cases (mean = 11.38. see Tab. II-A). The by far most frequent value was 11 mm in 29 cases

(47.5%). In one case, a very eccentric tunnel (then abandoned) was found; it was so eccentric that it was separated from the outside by only 1 mm of wooden wall. Females always dig upwards, but they first dig a 10-30 mm long ditch in the downward direction for collecting shavings. According to the inside features of the wood, the ascending tunnel is excavated to a maximum of 210 mm, or a minimum of 42 mm; in one case the ascending tunnel was not present (mean = 139.67; St. Dev. = 61.06; Var. = 3728.75). Once the ascending tunnel is over, the descending tunnel is from a minimum of 55 mm to a maximum of 245 mm (in the latter case the entrance hole was dug at only 15 mm from the top of the pole and only a descending tunnel resulted) (mean = 132.3; St. Dev. = 54.90; Var. = 3014.23). When nest digging is over, the base of the pole or branch is covered with shavings which make the nest recognizable. After the inferior tunnel has been lengthened, the shavings are removed by the bees which collect them by their forelegs and head, put some shavings under their body and move backwards as far as the entrance; then they come out of the tunnel with their abdomen appearing first and carry the shavings outside by their legs. The operation may be repeated two or three times. Nest digging takes as much as about 8 hours.

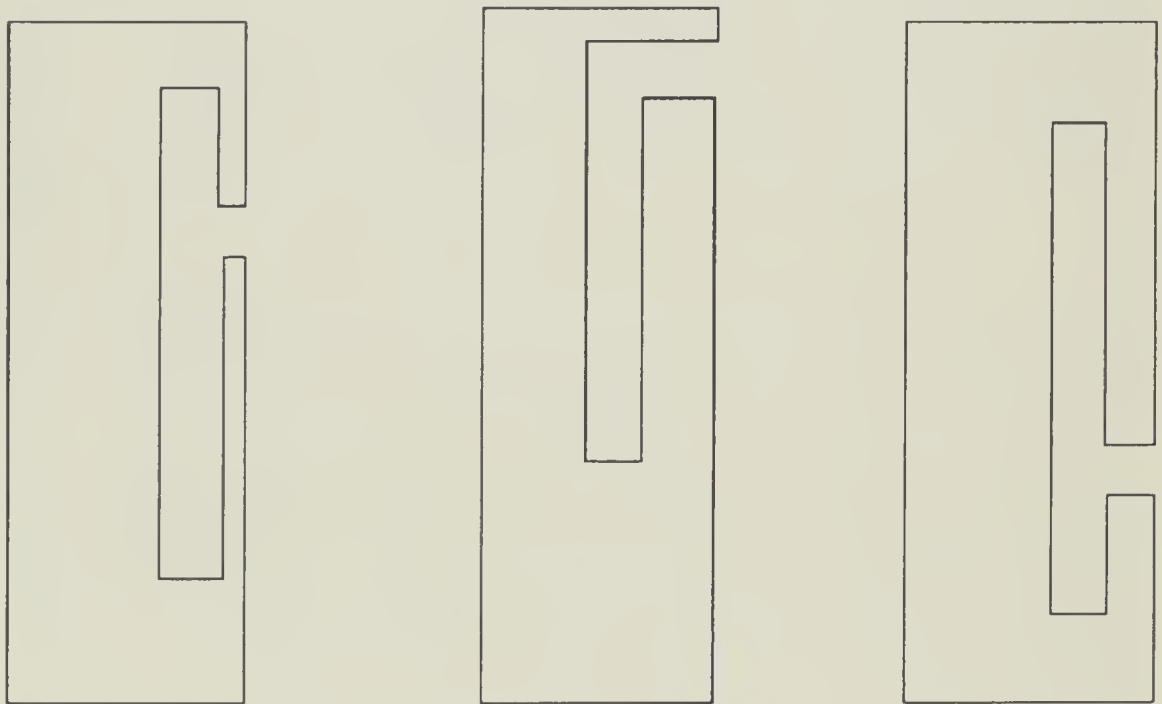


Fig. 1 – Morphology of unbranched nest observed in this area.

Fifty-two of the 61 holes (85.2%) found in these years (48 abandoned nests + 13 complete nests) were situated at a height exceeding 41% of the total length of the poles or branches, and 36 of 61 (59.0%) were situated at a height exceeding 70% of the total length. Furthermore, only 4 holes (6.5%) were at a distance lower than 500 mm from the ground, including two abandoned nests located at 50 and 20 mm. The least diameter of poles and branches with nests was 30 mm; the least circumference was 97 mm. The distance from the base was <900 mm only in 4 of the 13 nests in poles

or branches (30.8%). The average length of the whole nest was 272.54 mm (St. Dev. = 55.21; Var. = 3048.67). Entrance locations are reported in table IV.

In 1994 two branched nests were discovered in a rotten trunk of *P. persica*. Their measures are reported in table III. The total length of the nest was huge, about 3 times longer than those excavated in poles (see tab. III and tab. II-B). It was not possible to follow up the digging behavior in these two nests, because they were discovered in September and did not contain adults, but only evidences of the cells. Both nest entrances were excavated under a protruding mushroom, that acted as an entrance-roof.

From 1989 to 1994, the number of complete and abandoned nests in poles, branches and trunks remarkably decreased (Tab. V).

Twenty-two out of the 27 entrances in the poles are in the N-S direction.

Nest building – Canes.

Excavation in a cane is started only when the substrate is suitable; therefore, once started, the nest is never abandoned. Canes must have the same characteristics as poles and branches; furthermore, they must be free from other animals living in the substrate. The nests observed in canes had a thick wall, not inferior to 2 mm; the diameter of the entrance hole was between 11-13 mm in 67.7% cases, and only in 3 cases the diameter was >14 mm (6.0%) (mean = 12.30. see tab. VIII-A, B); the minimum cane height from the ground was 860 mm; 67.7% of the nests was situated at a height between 91 and 150 mm from the ground (Tab. VI). Another important character is the length of the initial internode (I); in fact, if it is too short, the septum between the first and the second internode is broken. Furthermore, the cane wood must be, at the most, variegated with black. No nest was excavated in rotten canes (M), although they accounted for 20% of the canes in the area (tab. VII).

In 47 out of 59 nests (79.7%) only the first internode was used; in 11 (18.6%) the first septum were broken, and thus the second distal internode was occupied; in 1 nest (1.7%) the first and second septa was broken, and the third distal internode was occupied.

The average length of the hollow cane containing a nest was 239 mm long.

Whether they are in canes or in poles and branches, old nests can be used many times, for as many as 4 years.

In canes there is not a preferential direction (tab. IV).

Table I – Metric characteristics of the nests abandoned before completion.

Pole Number	Length Ascending Chamber	Length Descending Chamber	Total Length
I	50	22	83
II	0	80	91
III	15	0	26
IV	0	25	36
V	46	46	103
VI	0	6	17
VII	0	22	33
MEAN *	37	33.5	55.6

* = Zero values are not considered for the mean.

Table II-A – Per cent distribution of entrance diameters (in mm) and univariate statistics (Sokal & Rolf, 1981; Martin & Bateson, 1993).

Hole Diameter	8	9	10	11	12	13	14	15	16	17	18	19	20	TOT.
Number Cell observed	1	2	10	29	13	2	1	0	1	1	0	0	1	61
%	1.6	3.3	16.4	47.5	21.3	3.3	1.6	0	1.6	1.6	0	0	1.6	99.6
mean	standard deviation				variance				mediane					
11.38	1.78				3.17				11					

Table II-B – List of horizontal and vertical poles and branches where *X. violacea* nests (in mm)

co de	ye ar	ty pe	sta te	use	pole heig ht	pole diam	apex hole dist.	base hole dist.	L.A. T.	L.D. T.	sub circ	sub diam	ent dir	ent dep th	LT nest	grou nd dist.
M1	86	Pp	Me	Sc	1800	11	432	1357	210	63	150	50	N	42	284	–
M8	86	Pp	Me	Sc	1508	11	560	937	154	130	280	86	S	29	295	–
M7	86	Pp	Me	Sc	1485	10	471	1004	105	160	172	53	S	22	275	–
M4	86	Pp	B	Sc	1112	12	290	810	81	129	108	35	E	17	222	–
M1	87	Pp	1/2M	Sr	1571	11	570	990	210	110	130	40	N	25	331	–
M2	87	Pp	1/4M	Sc	720	20	15	705	–	245	110	30	N	19	265	–
M3	87	Rr	M	No	2360	9	740	1610	210	125	210	65	S	100	344	–
M4	88	Pp	B	Sc	1641	11	190	1440	42	126	97	30	N	20	179	–
M2	90	Pp	Me	Sc	2147	12	1345	790	120	55	290	68	N	40	187	–
Mc	91	Rs	M	No	2946	11	405	2530	125	180	118	41	S	21	316	–
P2	88	Pp	B	No	630	17	0	630	0	300	119	33	S	-	300	1400

Hole diam = hole diametre. L. A. T. = lenght of ascending tunnel. L. D. T. = Length of descending tunnel. Sub circ = substrate circumference. Sub diam = substrate diametre. Ent dir = entrance direction. Ent depth = entrance depth. L. T. Nest = total length of nest tunnels.

Table III – Metric characteristics of two ramified nests found in September 1994. (in mm).

NEST	M 94/1	M 94/2
Ground hole distance	1950	700
Apex hole distance	150	1400
Hole diameter	11	11
Hole depth	26	35
Trunk circumference	260	285
Trunk diameter	65	97
Ascending tunnel 1	94	92
Ascending tunnel 2	150	101
Ascending tunnel 3	100	112
Ascending tunnel 4	100	121
Ascending tunnel 5	–	108
Ascending tunnel 6	–	100
Ascending tunnel 7	–	55
Descending tunnel 1	155	43
Descending tunnel 2	75	89
Descending tunnel 3	95	–
Total lenght of tunnel	769	821

Table IV – Entrance direction of complete and abandoned nests.

Orientation	Abandoned	Complete		Total
		Poles/branches	Canes	
SOUTH	5	6	11	21
NORTH	6	5	11	23
WEST	1	0	15	16
EAST	1	2	13	17
NW	–	–	3	3
SW	–	–	1	1
SE	–	–	5	5

Table V – Yearly course of building nests divided in substrata and type of nest.

Substratum	Abandoned	Complete			Total nest completed
		Poles/branches		Canes	
		Ramified	Not ramified		
Nest type					
1986	9	0	4	4	8
1987	12	0	3	7	10
1988	5	0	2	6	8
1989	0	0	0	9	9
1990	3	0	1	8	9
1991	1	0	1	4	5
1992	2	0	0	7	7
1993	2	0	0	3	3
1994	0	2	0	11	13

Table VI – Classes of distance from the ground for nests in canes (in mm).

Ground Distance	N° Nests	%
710-900	5	8.5
910-1100	20	33.9
1110-1300	8	13.5
1310-1500	12	20.3
1510-1700	7	11.9
1710-1900	4	6.8
1910-2100	3	5.1
2110-2300	0	0.0

Table VII – Wood condition of canes containing nests compared with that of all canes present .

Wood conditions	Number of nests	%	N° present canes	%
B	31/59	52.5	9	18.0
G	24/59	40.7	10	20.0
S	4/59	6.8	21	42.0
M	0/59	0.0	10	20.0

Table VIII-A – Nest entrance diameters in canes compared with holes diameters in all the canes of the study area.

Millimetres	N° observed nests	%	N° present canes	%
6	0	0	1	2.0
7	0	0	3	6.0
8	0	0	4	8.0
9	1	1.7	1	2.0
10	6	10.2	2	4.0
11	11	18.6	5	10.0
12	14	23.7	4	8.0
13	15	25.4	4	8.0
14	9	15.2	4	8.0
15	1	1.7	2	4.0
16	2	3.4	1	2.0
17	0	0	2	4.0
18	0	0	2	4.0
19	0	0	2	4.0
20	0	0	6	12.0
21	0	0	4	8.0
22	0	0	1	2.0
23	0	0	2	4.0
TOTALS	59	99.9	50	100.0

Table VIII-B – Univariate statistics on nest entrance in canes (Sokal & Rolf, 1981; Martin & Bateson, 1993).

mean	standard deviation	variance	mediane
12.30	1.50	2.25	12

Discussion

From the large number of abandoned nests it can be inferred that this is quite a frequent phenomenon. To be a suitable substrate, a pole or a branch must be in a good state, i.e. compact but not too hard and free from potential clutch predators. Cracks and rottenness can cause flooding of the nest in case of rain and breakage of the nest in case of strong wind. As the ants are nest predators, all the substrata with ant nests are rejected. The poles and the branches lying on the ground are also avoided because they are subjected to predation, flooding and burial; in addition, worm-eaten substrata are avoided because they are easily broken. These considerations are also valid for canes, in fact, a rotten cane lets water pass inside easily (see tab. VII). The diameter of a pole or a branch is also important for a nest substratum to be suitable: in fact, too narrow a substratum might cause the death of the brood for the following reasons:

1. the great fragility, increased by the tunnel presence;
2. eccentricity of the tunnel, that might cause nest flooding for the high permeability of the thin nest wall.

The number of abandoned and complete nests in poles and branches has declined since 1989. This is due to the increasing use of canes by the farmers since 1989. Canes are the ideal substratum for the nests of this species, since they do not require hard digging, but only the demolition of possible septa at the level of the internodes. The nest is less recognizable both on sight and in the long run, since there are no shavings at its base as in poles and branches, and therefore, as has been observed, it is less subject to predation by *Podarcis sicula*.

Furthermore, shavings give off an intense «nest smell» that derives from spittle, pollinic paste, shavings and other secretions of *X. violacea*. This smell may attract the ants *Cremastogaster scutellaris*, which also prey on nests (see also Anzenberger, 1986). In fact, 2 out of 59 nests in canes and 2 out of 13 in poles and branches were preyed on by *P. sicula* in the study period. *C. scutellaris* preyed on 1 out of 59 nests in canes and 1 out of 13 in poles and branches. Nests in canes appear more subjected to predation by other females of *X. violacea*; in fact, if females in search of pollen find nests unattended temporarily or for the death of the founding female, they not only take away the pollen paste in the nest, destroying the cells, but they also feed on eggs. This was observed in 5 nests in canes but not in poles and branches.

The maximum diameter of the entrance hole is an antipredatory measure, essentially against *P. sicula*; it may be also related to the stability of the septa built for delimiting the cells. The distance from the ground is another very important antipredatory measure, since nests close to the ground are more easily accessible (see also: Kapil & Dhaliwal, 1968).

The length of the internode where the nest is situated, is smaller than the length of the whole nest excavated inside poles and branches. This may depend on the canes being filled up with less long or less numerous cells than those in the poles. Females do not seem to prefer any direction (descending or ascending) in poles for extending nest tunnels (nel testo italiano il concetto è diverso).

The typical *X. violacea* nest in this area is not ramified, which is no

doubt an adaptation to poles used in agriculture which have a smaller diameter than a trunk, and hence do not allow branching. Obviously, ramified nests are always excavated in trunks, as happens for other species of the genus and also for the same *X. violacea* in other areas (Van Lith, 1955; Croveti, 1963). Dindo et al. (1992) have described *X. violacea* nesting and overwintering in fossil trunks.

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